

## Fabrication of Si/Si<sub>1-x</sub>Ge<sub>x</sub>O<sub>2</sub> Heterojunctions by Molecular Beam Epitaxy and Stain Etching\*

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While Si/Si<sub>1-x</sub>Ge<sub>x</sub> heterojunction technology has seen considerable progress over the last decade, the large lattice mismatch and small conduction-band discontinuity in the system significantly limit the range of device structures which are possible. A means of creating heterojunctions and multilayer structures with the crystalline-Si/amorphous-SiO<sub>2</sub> system has been described as a potential giant step forward.<sup>1</sup> We report progress toward this goal, demonstrating a technology for producing amorphous Si<sub>1-x</sub>Ge<sub>x</sub>O<sub>2</sub> layers as thin as 5 nm sandwiched by single-crystal Si.

The starting structures are grown by molecular beam epitaxy and consist of thin Si<sub>0.7</sub>Ge<sub>0.3</sub> layers embedded in Si. It was shown previously that mesas formed from such structures and subjected to an H<sub>2</sub>:HNO<sub>3</sub>:H<sub>2</sub>O stain etch porosify preferentially at the Si<sub>0.7</sub>Ge<sub>0.3</sub> layers.<sup>2</sup> Ultra-thin ( $\approx$  5 nm) layers can be formed over large areas by forming *vias* through which the etchant can pass rather than mesas. This could be accomplished lithographically, but initially we have chosen to use columnar epitaxy<sup>3</sup> of CoSi<sub>2</sub> for this purpose. The columns of silicide are selectively removed by wet etching, after which stain etching is carried out to porosify the Si<sub>0.7</sub>Ge<sub>0.3</sub> layer. The sample is then oxidized in a furnace at 700°C. The final structure as characterized by transmission electron microscopy consists of a  $\approx$  7-nm-thick oxide layer with single-crystal Si underneath and single-crystal Si containing a random array of holes (typical spacing of  $\approx$  0.1  $\mu$ m) above.

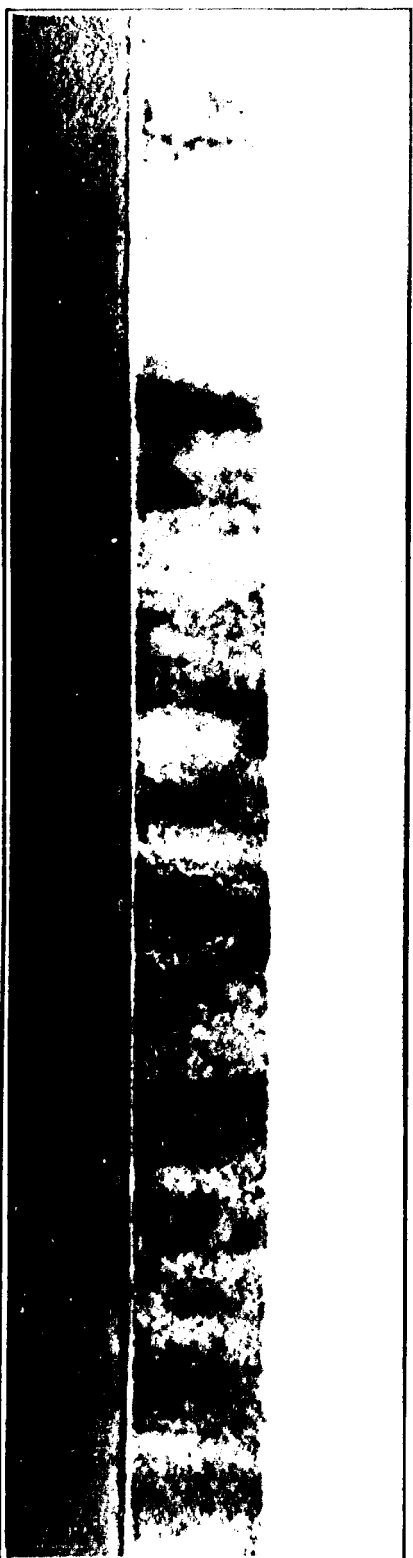
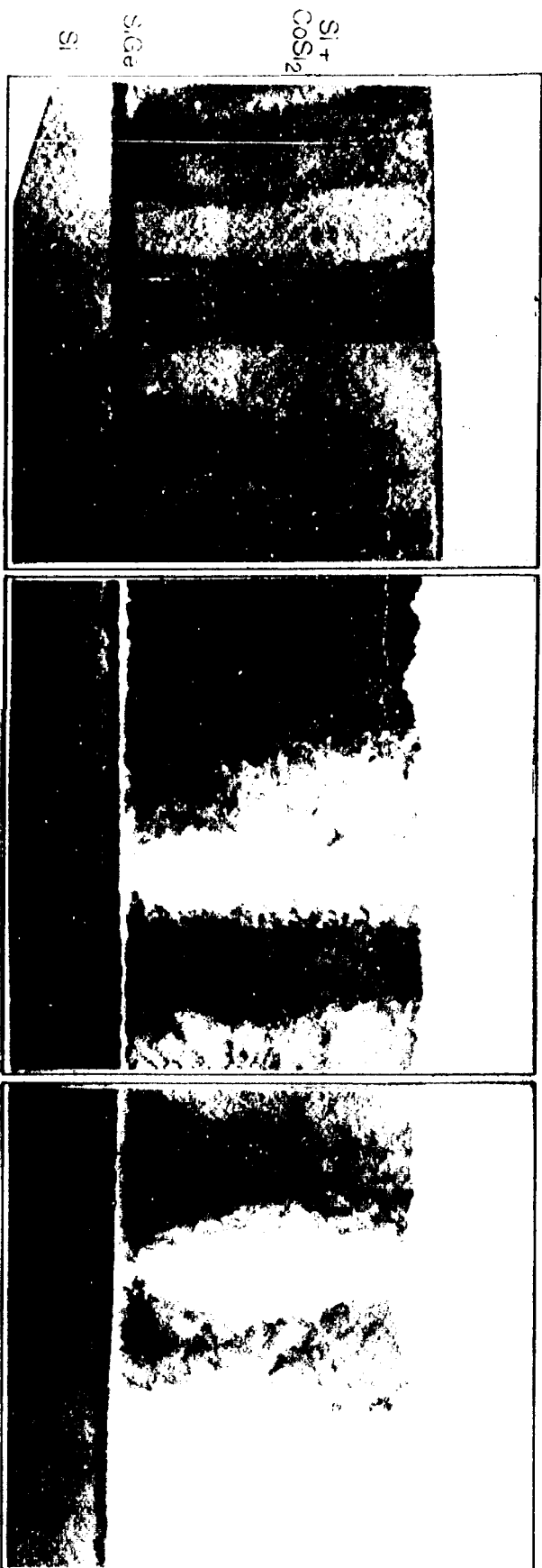
This work will be extended to double barriers of oxide with a thin single-crystal Si layer sandwiched in between. Optical characterization of this Si quantum well will then be carried out. In addition, further structural and chemical analyses will be carried out on the oxide layers.

1. R. Tsu, E.H. Nicolian, and A. Reisman, Appl. Phys. Lett. **55**, 1897 (1994).

2. R.W. Fathauer, T. George, E.W. Jones, W.T. Pike, and R.P. Vasquez, Appl. Phys. Lett. **61**, 2350 (1992).

3. R.W. Fathauer, C.W. Nieh, Q.F. Xiao, and S. Iijima, Appl. Phys. Lett. **55**, 247 (1989).

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Cross-sectional transmission electron micrographs of a sample at three stages of processing. At upper left, the as-grown structure is shown with epitaxial columns of  $\text{CoSi}_2$  embedded in single-crystal  $\text{Si}$ , on top of a  $\text{Si}_0.7\text{Ge}_{0.3}$  layer, on  $\text{Si}$ . At upper middle, a sample is shown after the silicide columns have been preferentially etched out and the sample submerged in the stain-etch solution, so that the  $\text{Si}_0.7\text{Ge}_{0.3}$  layer, is porosified. At upper right and bottom, a sample is shown after furnace oxidation to convert the porous layer to oxide.